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INFLUENCE OF A 35 DAY FAST ON PHYSICAL PERFORMANCE  
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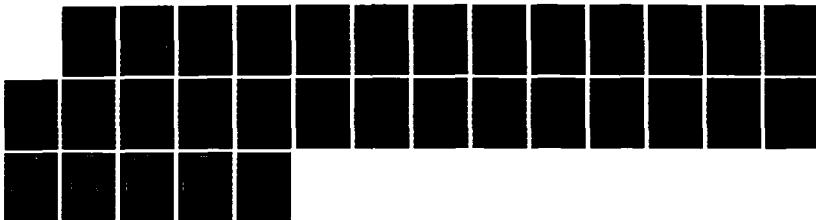
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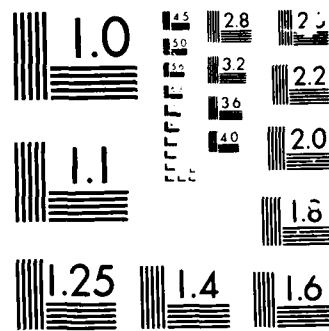
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The influence of a 14h fast or a 3.5 day fast on physical performance was investigated in 8 young men. In both conditions they were tested for isometric strength, isokinetic strength (elbow flexors, 30°/sec), anaerobic capacity and aerobic endurance. Anaerobic capacity was evaluated by having subjects perform 50 rapidly repeated isokinetic contractions of the elbow flexors at 180°/sec. Aerobic endurance was measured as time to volitional fatigue during a cycle ergometer exercise at 45% $\dot{V}O_{2,max}$ . Measures of $\dot{V}O_2$ , $\dot{V}_E$ , heart rate, and ratings of perceived exertion were obtained prior to and during the cycle exercise. The		

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3.5 day fast did not influence isometric strength, anaerobic capacity or aerobic capacity or aerobic endurance, but isokinetic strength was significantly reduced ( 10%) at both velocities.  $VO_2$ ,  $V_E$  and perceived exertion were not affected by fasting. Fasting significantly increased heart rate during exercise but not at rest. It was concluded that there are minimal impairments in physical performance as a result of a 3.5 day fast provided there is little physical activity during the fasting period.

INFLUENCE OF A 3.5 DAY FAST ON PHYSICAL PERFORMANCE

RUNNING HEADING: FASTING AND PERFORMANCE

by

Joseph J. Knapik, M.S., Sc.D.

Bruce H. Jones, M.P.H., M.D.

Carol Meredith, Ph.D.

William J. Evans, Ph.D.

US Army Research Institute of  
Environmental Medicine, Natick, MA 01760

Massachusetts Institute of Technology,  
Cambridge, MA

USDA Human Nutrition Research Center on Ageing  
Tufts University  
Boston, MA

Send Correspondance and Reprint Requests to:

Joseph Knapik  
Army War College  
Box 554  
Carlisle, PA 17013  
(717) 245-4511

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## ABSTRACT

The influence of a 14h fast or a 3.5 day fast on physical performance was investigated in 8 young men. In both conditions they were tested for isometric strength, isokinetic strength (elbow flexors, 30°/sec and 180°/sec), anaerobic capacity and aerobic endurance. Anaerobic capacity was evaluated by having subjects perform 50 rapidly repeated isokinetic contractions of the elbow flexors at 180°/sec. Aerobic endurance was measured as time to volitional fatigue during a cycle ergometer exercise at 45%  $\dot{V}O_2$  max. Measures of  $\dot{V}O_2$ ,  $\dot{V}_E$ , heart rate, and ratings of perceived exertion were obtained prior to and during the cycle exercise. The 3.5 day fast did not influence isometric strength, anaerobic capacity or aerobic endurance, but isokinetic strength was significantly reduced (~10%) at both velocities.  $\dot{V}O_2$ ,  $\dot{V}_E$  and perceived exertion were not affected by fasting. Fasting significantly increased heart rate during exercise but not at rest. It was concluded that there are minimal impairments in physical performance as a result of a 3.5 day fast provided there is little physical activity during the fasting period.

Keywords: Fasting, starvation, muscle strength, isometric strength, isokinetic strength, aerobic endurance, anaerobic capacity, oxygen uptake, ventilation, heart rate, perceived exertion.

The maintenance of strength and endurance under adverse physiological conditions such as lack of food has long been recognized as critical to the performance of soldiers (16). Scenarios where physical activity may be required while fasting may include prolonged confinement in chemical protective suits, contamination of foodstuffs by nuclear or biological agents, periods requiring rapid movement without time for consuming food and periods of nonsupply in remote areas. In these and other situations the metabolic changes that occur during the early stages of fasting might be expected to impair muscle function. These changes include increased actomyosin breakdown (22), greater net protein breakdown and decreased proportion of polyribosomes in skeletal muscle (23,31), atrophy of muscle tissue (28) and loss of muscle glycogen (14). However the effects of fasting on tasks requiring voluntary muscular effort have not been well characterized. Previous studies have not controlled the relative exercise intensity (13,16,20) or have not maintained rest during the initial period of adjustment to fasting (5,13). Studies on isometric strength have shown varied results (3,5,29) and anaerobic capacity has not been evaluated.

The purpose of the present study was to determine whether or not a 3.5 day fast impaired voluntary physical performance in young men. Performance measures included evaluations of isometric and isokinetic strength, anaerobic capacity, aerobic endurance, and various cardiorespiratory measures during low intensity exercise.

## METHODS

### Subjects

Subjects were 8 male soldiers. They gave their voluntary, written consent to participate in this investigation after being informed of the purpose, procedures and risks of the study in accordance with Army Regulation 70-25. The study protocol was approved by the Human Use Review Committees of the US Army Research Institute of Environmental Medicine and the Massachusetts Institute of Technology.

### Study Design

The men were studied in 3 sessions. In the first session physical characteristics and  $\text{VO}_2$  max were determined. In the next 2 sessions subjects were tested after either 14h or 3.5 days of fasting. The 14h fast was termed the post absorptive (PA) test and the 3.5 day fast was termed the fasted (F) test. These 2 sessions were separated by 14 to 35 days and were administered such that 4 subjects tested first in the PA state and the other 4 subjects first in the F state.

For 4 days prior to the PA or F tests subjects consumed a standard, balanced diet consisting of 12% protein calories, 53% carbohydrates calories, and 34% fat calories. In the PA session subjects resided overnight in a Clinical Research Center (CRC) and were tested the following morning. In the F session



subjects resided in the CRC for 3 days and were tested on the morning of the fourth day. They performed a minimal amount of physical activity while fasting. In both sessions subjects were under the constant supervision of the CRC nursing staff. While fasting only distilled water and selected herbal teas were consumed.

#### Initial Testing

Body composition, height, weight, and  $\text{VO}_2$  max were determined. Body composition was estimated from 4 skinfolds using the equations of Durnin and Womersley (7).  $\text{VO}_2$  max was obtained using a mechanically braked cycle ergometer (Monark<sup>R</sup> Model 864). A discontinuous, incremental protocol was used. Subjects cycled for 4 min, rested 5-10 min then returned for another exercise period. Initial power output was 60W and this was increased 30W in each successive exercise period. Near the end of each exercise period, 2, 30 sec expired gas samples were collected into vinyl Douglas bags. These samples were analyzed for oxygen concentration (Applied Electrochemistry<sup>®</sup> Model S-3A) and carbon dioxide concentration (Beckman<sup>®</sup> Model LB-2). Gas volumes were measured with a Tissot spirometer. Subjects were monitored electrocardiographically throughout the test. The  $\text{VO}_2$  max was defined as a change of less than 0.2 l/min between successive exercise periods or an inability of the subject to continue because of fatigue.

### Testing in PA and F Conditions

Testing in both the PA and F sessions was identical. Subjects were awakened at 0600 hours. Muscular strength and anaerobic capacity were assessed from 0700-0800 hours. The muscular strength of the upper torso, handgrip and elbow flexors was evaluated using previously described techniques (17,26). For the upper torso measures subjects were seated in a chair with a seat belt around their waist. With both hands they grasped a bar just forward of their head such that their upper arm was parallel to the floor and there was a 90° angle at their elbow joint. On command, they pulled down as hard as possible on the bar exerting an isometric force that was measured with a strain gauge. Hand grip strength was measured by having subjects squeeze a pistol-like grip as hard as possible and recording the isometric force with a strain gauge. For the elbow flexor measures subjects was seated in a large chair. Well padded shoulder restraints were placed over both shoulders and straps secured subjects at the waist and thighs. They were then attached to a Cybex® isokinetic dynamometer by a clamp at the wrist. On command, subjects dynamically pulled up on the wrist clamp and the peak torque produced was measured. Two isokinetic velocities, 30°/sec and 180°/sec, were tested. Strong verbal encouragement was given during all strength tests. Each strength test was performed 3 to 5 times and the criterion strength score was the mean of the 3 highest values.

Anaerobic capacity was measured using a modification of the Thorstensson test (30). This test is closely correlated with the Wingate test, (24) another measure of anaerobic capacity. Subjects were seated in the same chair used for the elbow flexion strength tests. On command they pulled up on the wrist clamp as hard as possible, relaxed as the clamp moved down, then immediately pulled up again. This cycle was repeated for 50 continuous contractions and peak torque was recorded for each contraction. The isokinetic velocity was 180°/sec.

From 0900 to 1130 hours subjects rested quietly in bed. Beginning at 0930 expired gas samples were collected at half hour intervals and heart rates (HR) were recorded. At 1200 hours subjects began exercising on a cycle ergometer at 45% of  $\dot{V}O_2$  max and continued until they were too fatigued to go on. The cycle cadence was maintained at 60 RPM. The time to volitional fatigue was recorded as the aerobic endurance measure. Evans et al. (9) have shown that soldiers will select an energy expenditure of 45%  $\dot{V}O_2$  max when asked to walk as rapidly as possible for a long period of time. Therefore, the intensity of exercise was judged to be similar to field conditions.

At 10, 20, 30, and 60 minutes of exercise and near exhaustion, expired gases, HR and perceived exertion (2) were obtained. Expired gases were analyzed to obtain  $\dot{V}O_2$  and  $\dot{V}_E$  as described above. One half hour after the completion of exercise in the PA session, a muscle tissue sample was obtained

from the vastus lateralis muscle by the needle biopsy technique (1). The sample was mounted in tissue tex<sup>®</sup>, frozen in isopentane (cooled in liquid nitrogen), and stored for histochemical analysis. Muscle sections were stained for myofibrillar ATPase to determine muscle fiber type (4).

#### Statistical Analysis

Values obtained in the PA and F sessions for isometric strength, isokinetic strength and aerobic endurance capacity were compared by a paired t-test. Data on anaerobic capacity, perceived exertion,  $\dot{V}O_2$ ,  $\dot{V}_E$  and HR were analyzed using a 2-way analysis of variance with repeated measures; statistically different results were further analyzed using the Tukey test.

### RESULTS

The physical characteristics of the subjects obtained in the initial session are shown in Table 1. The muscle fiber distribution showed an unusually high proportion of Type II fibers. Body weights taken in the initial session (Table 1) were not significantly different from body weights taken at 8h of fasting ( $76.7 \pm 13.0$  kg). At 80h of fasting body weights were significantly reduced ( $73.8 \pm 12.4$  kg) compared to the other 2 time periods.

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PLACE TABLE 1 ABOUT HERE

Strength data are presented in Table 2. There were no significant differences between the PA and F sessions for isometric upper torso or hand grip strength. However, fasting significantly reduced isokinetic strength at both velocities. Figure 1 depicts the results of the modified Thorstensson test. Analysis of variance revealed no significant difference between the PA and F sessions and no significant time x nutritional state (PA VS F) interaction.

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PLACE TABLE 2 AND FIGURE 1 ABOUT HERE

Table 3 shows that the cycle times to exhaustion were lower by an average 21 min in the F session compared to the PA session but this difference was not statistically significant ( $t=2.00$ ,  $p > .05$ ). At 20 min of exercise the actual exercise intensity was  $46 \pm 3\%$   $\text{VO}_2$  max in both the PA and F sessions. Power output was also identical in both sessions and was  $86 \pm 25$  W. Table 3 also shows ratings of perceived exertion. These were not significantly different between the PA and F sessions. Exertion was initially perceived as "very light" and progressed up to "very hard" at exhaustion.

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PLACE TABLE 3 ABOUT HERE

Cardiorespiratory data are shown in Figure 2. There were no significant differences between the PA and F sessions for  $\dot{V}O_2$  (Figure 2a) and  $\dot{V}_E$  (Figure 2b). HR (Figure 2c) at rest was not affected by fasting but during exercise, HRs were significantly higher in the F session than in the PA session.

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PLACE FIGURE 2 ABOUT HERE

## DISCUSSION

Results of the present study indicated that a 3.5 day fast did not affect isometric strength, anaerobic capacity or aerobic endurance during low intensity exercise. It appears that the metabolic changes that occur in this time period (14,22,23,28,31) are not of sufficient magnitude to affect voluntary performance on these tasks provided little physical activity is performed during the fast.

Studies that have evaluated maximum voluntary isometric strength during fasts of 3 to 4 days have reported small and generally not significant changes in isometric strength, in agreement with the present study (3,5,27,29). However, isokinetic strength has not been previously evaluated and in this study was found to be significantly decreased at both 30°/sec and 180°/sec. These decrements, although small, occurred in 7 of the subjects at the slower velocity and 6 of the subjects at the faster velocity. While there are a great deal of similarities between isometric and isokinetic modes of testing some differences still remain. There is a relatively close relationship between isokinetic and isometric strength with correlations ranging from about 0.7 to 0.8 (18). However, this leaves about 35% to 50% of the variance between these 2 modes of testing unaccounted for possible reflecting central nervous system influences. Isokinetic strength training results in a transfer of strength gains to an isometric test but isometric strength training does not transfer to as great an extent to an isokinetic test (19).

Subjects in this study had an unusually high proportion of Type II muscle fibers and it may be argued that this made them more susceptible to fast induced atrophy. Two weeks of a hypocaloric diet has been shown to result in selective atrophy of Type II muscle fibers (28). However, it is unlike that any significant atrophy occurred in the present study after 3.5 days of fasting. It has been shown that fatiguability on the Thorstensson test is highly correlated with the percentage of Type II muscle fibers (30) but in this study there was no evidence of fast-induced changes in fatiguability. Further, subjects with a high percentage of Type II fibers have been shown to exert higher torque at 180°/sec than at 30°/sec (15). If selective atrophy had occurred it is possible that the fast-induced decline in torque would have been greater at 180°/sec than at 30°/sec; however, in the F session decreases in torque were similar at both contractile velocities.

There was no difference in aerobic endurance between the PA and F sessions and subjects had very similar ratings of perceived exertion in the 2 sessions. A decrease in the cycle times to exhaustion following fasting was expected because of reductions in muscle glycogen that have been shown to accompany short term fasting (14). On the other hand, ketosis and increased reliance on free fatty acid oxidation typical of fasting (25) do not in themselves alter the capacity for endurance exercise.



The cycle times to exhaustion seem short for endurance activity of this low intensity (10). Subjects in the present study had low proportion of Type I muscle fibers (30%). During low and moderate exercise intensities (30-60%  $\text{VO}_2$  max) it is predominately these fibers that are recruited. As these fibers become depleted of muscle glycogen a larger percentage of Type II fibers will become involved in force production (11) but Type II fibers have a much lower potential for oxidative metabolism (8). Thus, glycogen depletion in Type I fibers could have occurred early in exercise resulting in early recruitment of Type II fibers. Type II fibers could have rapidly used their available glycogen (since this is their predominate fuel source) and been less able to take advantage of the elevated free fatty acid levels typically seen later in exercise and during fasting (12) resulting in early volitional fatigue.

Other explanations for the short endurance times may be in methodology. Cycle ergometer exercise involves a smaller muscle mass than activities such as walking where longer endurance times have been reported (21). Thus there are fewer alternate muscle fibers that can be recruited for force production. Also, subjects in the present study had no previous experience with cycle ergometer exercise. The protocol of the present study strictly required subjects to maintain the pedal cadence at 60RPM

and fatigue was defined as an inability to continue this cadence despite strong verbal encouragement. Subjects were prohibited from extraneous movements such as swaying or standing up on the cycle. In addition, subjects were not currently engaged in any regular, vigorous aerobic activity.

The present study found no significant change in resting or exercising  $\dot{V}O_2$  and  $\dot{V}_E$  as a result of the fast. Exercise heart rates were elevated but resting heart rates were not. These results are generally in agreement with those of other studies that have had subjects fast and interpolated exercise on successive days of the fast (5,13,29). Consolazio et al. (5) had subjects perform low intensity exercise and did not find a significant decline in resting or exercising  $\dot{V}O_2$  until 5 to 9 days of fasting. Exercising  $\dot{V}_E$  decreased after 5 days of fasting while exercising heart rates increased at 2 to 5 days of fasting. The change in HR may be due to dehydration which is known to accompany short term fasting (6,29).

In conclusion a 3.5 day fast had no effect on isometric strength, anaerobic capacity or aerobic endurance of young men while the decrement in isokinetic strength was small. The absence of food for a period of a few days would seem to have little impact on voluntary functional capacity provided the individual performs minimal physical activity during the fasting period.

## ACKNOWLEDGEMENTS AND FOOTNOTES

## ACKNOWLEDGMENTS

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## FOOTNOTES

## NOTE 1

Joseph Knapik is currently the Exercise Physiologist at the Army Physical Fitness Research Institute, Army War College, Box 554, Carlisle, PA 17013. Bruce Jones is currently at the Division of Preventive Medicine, Walter Reed Army Institute of Research, Washington, DC.

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TABLE 1. PHYSICAL CHARACTERISTICS OF THE SUBJECTS

	Age (yrs)	Height (cm)	Weight (kg)	Body Fat (%)
M	22.5	172.5	76.8	16.4
SD	2.5	5.4	14.1	4.6

	<u>Muscle Fiber Type (%)</u>			VO <sub>2</sub> max (l*min <sup>-1</sup> )
	<u>Type I</u>	<u>Type IIa</u>	<u>Type IIb</u>	
M	29.6	36.6	33.7	3.25
SD	7.8	11.0	9.0	0.62

TABLE 2. STRENGTH IN THE POST ABSORPTIVE  
AND FASTED SESSIONS

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	<u>Post Absorptive*</u>	<u>Fasted*</u>	<u>t-Value</u>
<u>Isometric Strength</u>			
Upper Torso (kg)	98.9 $\pm$ 19.3	99.7 $\pm$ 19.6	0.29
Hand Grip (kg)	55.7 $\pm$ 12.3	57.0 $\pm$ 14.0	0.35
<u>Isokinetic Strength</u>			
<u>(Elbow Flexors)</u>			
30°/sec (NM)	63.6 $\pm$ 8.5	57.4 $\pm$ 11.1	2.98**
180°/sec (NM)	46.8 $\pm$ 5.7	43.1 $\pm$ 6.3	2.95**

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\*Values are Means $\pm$ SD

\*\*Statistically significant,  $p < 0.05$

TABLE 3. AEROBIC ENDURANCE AND RATINGS OF  
PERCEIVED EXERTION\* DURING CYCLE ERGOMETER  
EXERCISE AT 45% VO<sub>2</sub> MAX

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	<u>Post Absorptive**</u>	<u>Fasted**</u>
Aerobic Endurance		
(min to exhaustion at		
45% VO <sub>2</sub> max)	139 $\pm$ 36	118 $\pm$ 50
Perceived Exertion*		
at 10 min	9.3 $\pm$ 1.3	8.6 $\pm$ 2.4
at 20 min	9.9 $\pm$ 1.5	9.9 $\pm$ 2.7
at 30 min	11.0 $\pm$ 1.8	10.5 $\pm$ 2.8
at 60 min	12.6 $\pm$ 1.6	12.3 $\pm$ 2.8
at Exhaustion	16.6 $\pm$ 1.6	17.3 $\pm$ 1.4

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\*Borg Scale (2)

\*\*Values are Means  $\pm$  SD

## LEGENDS OF ILLUSTRATIONS

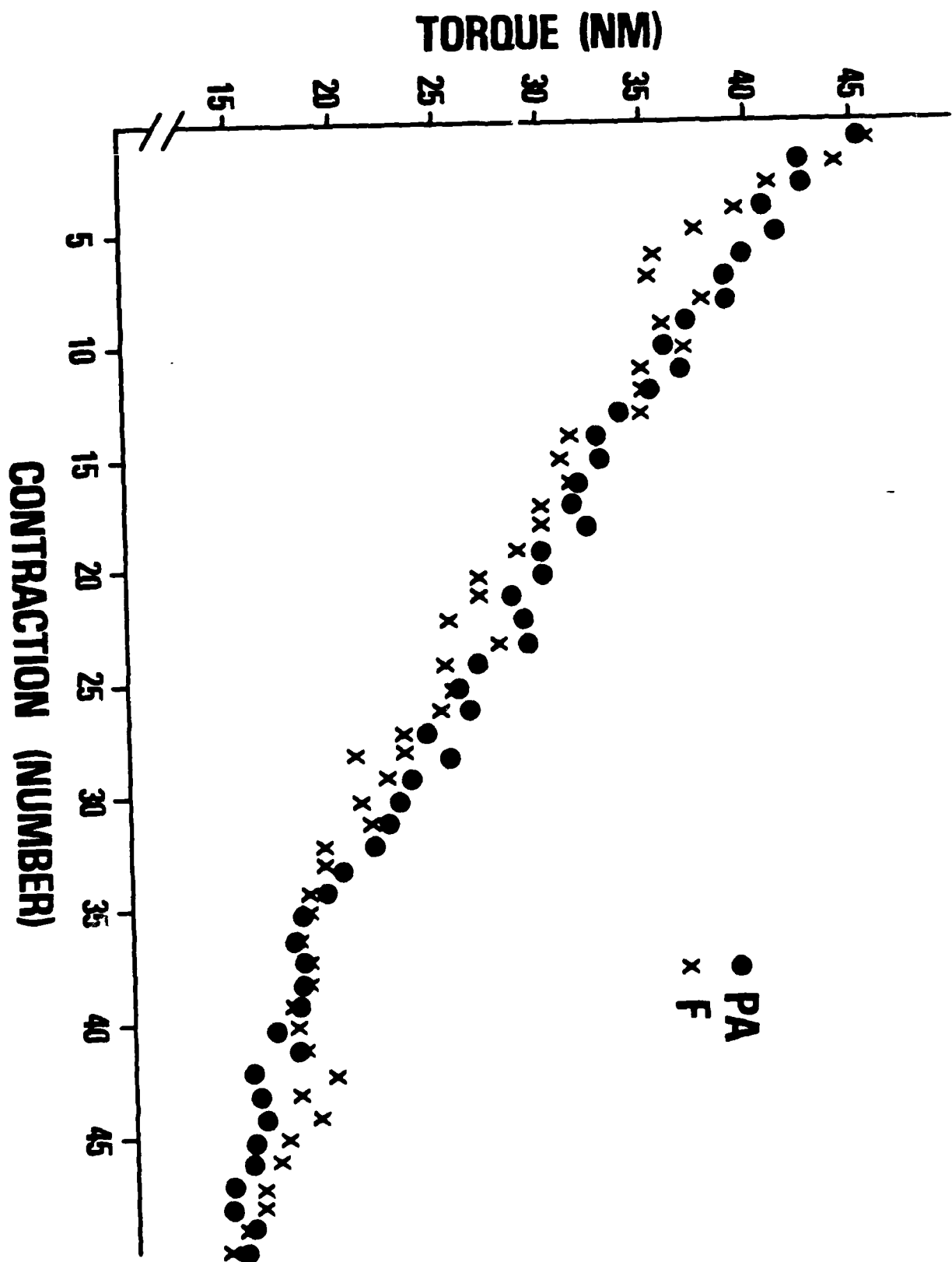
FIGURE 1. ANAEROBIC CAPACITY IN THE PA AND F SESSIONS

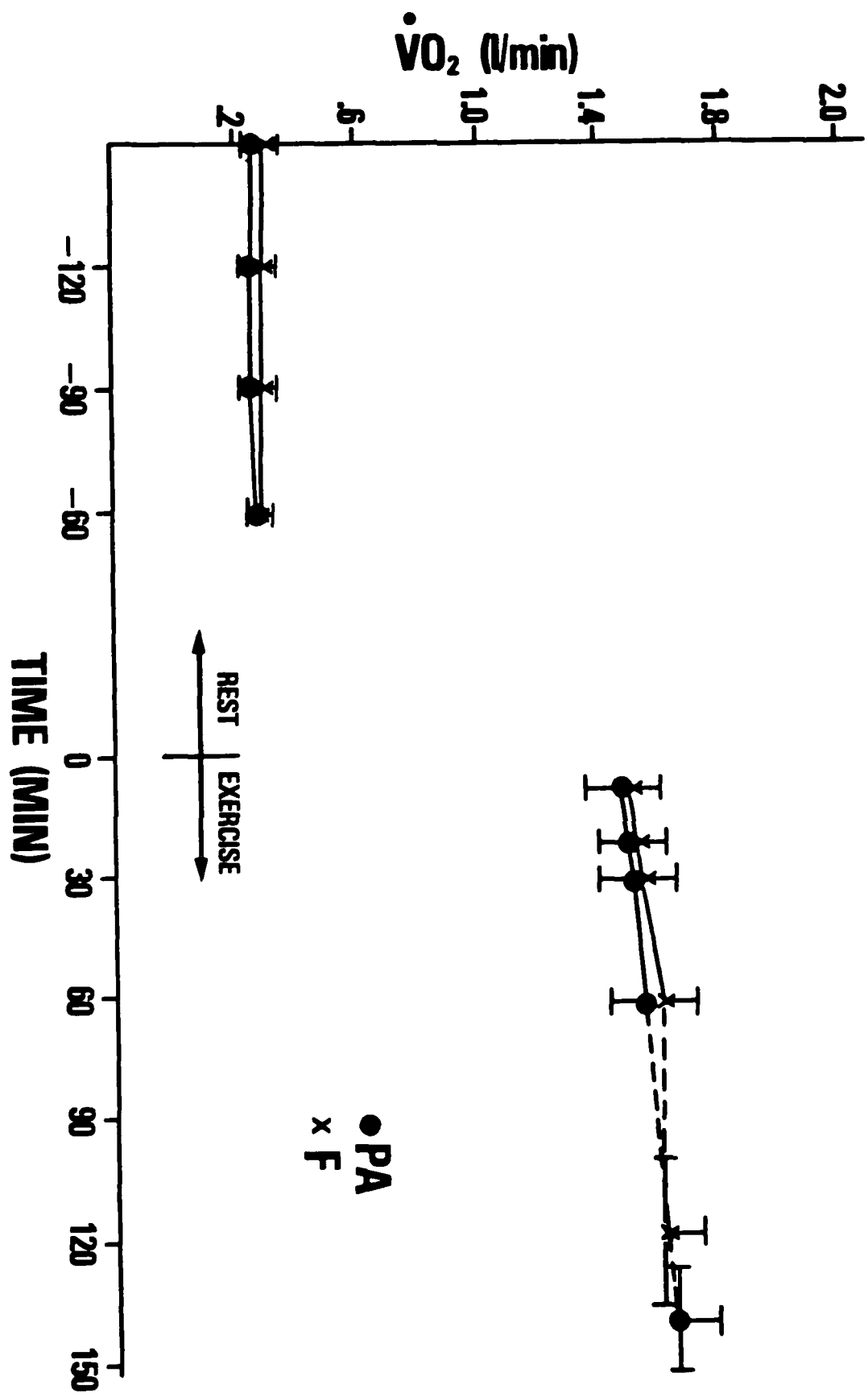
FIGURE 2.  $\dot{V}O_2$ ,  $\dot{V}_E$  AND HR AT REST AND DURING EXERCISE IN THE PA AND F SESSIONS. VERTICAL BARS DENOTE STANDARD ERRORS OF MEANS. HORIZONTAL BARS ARE STANDARD ERRORS OF EXERCISE TIME TO EXHAUSTION.

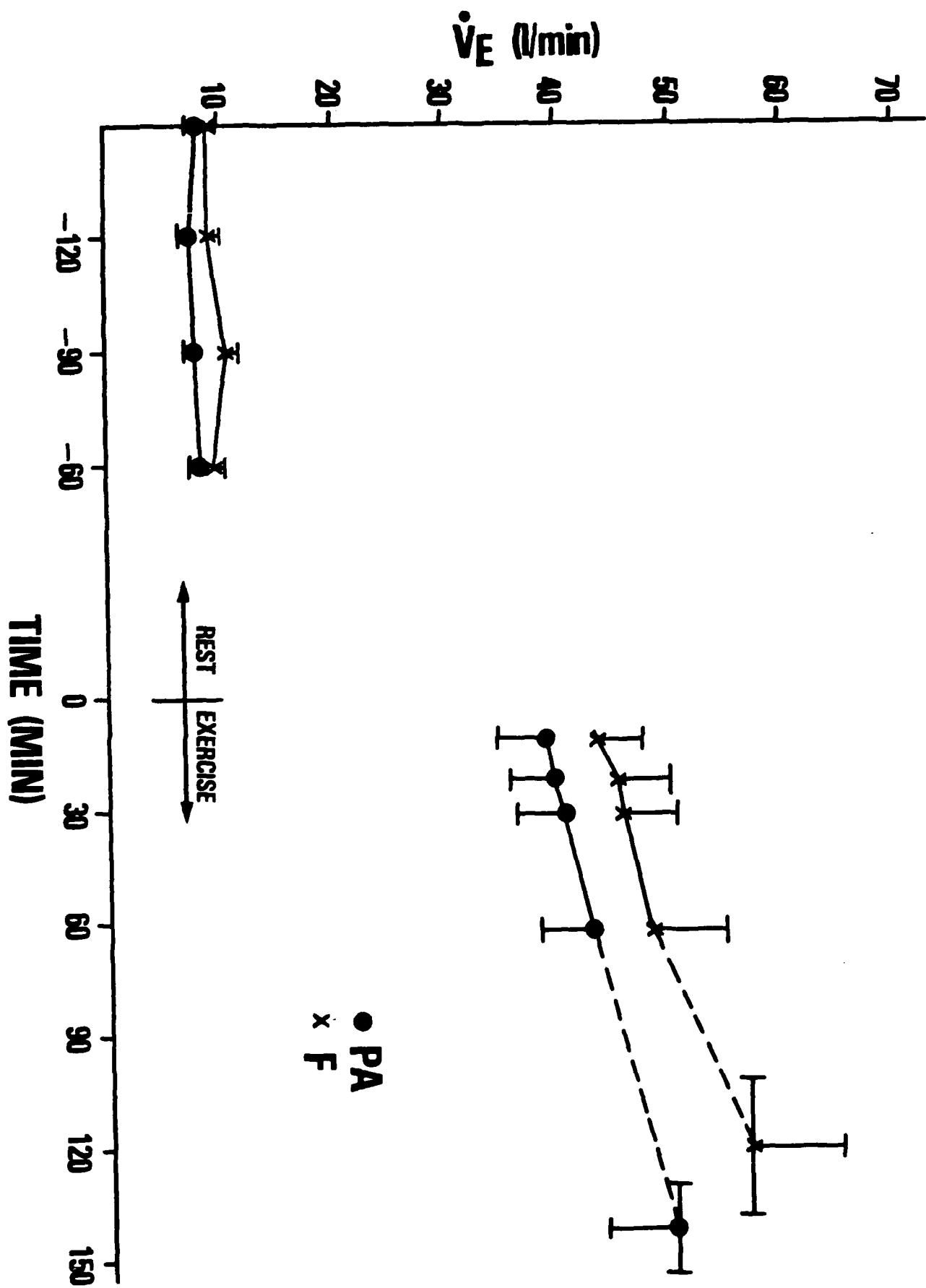
FIGURE 2A. OXYGEN UPTAKE

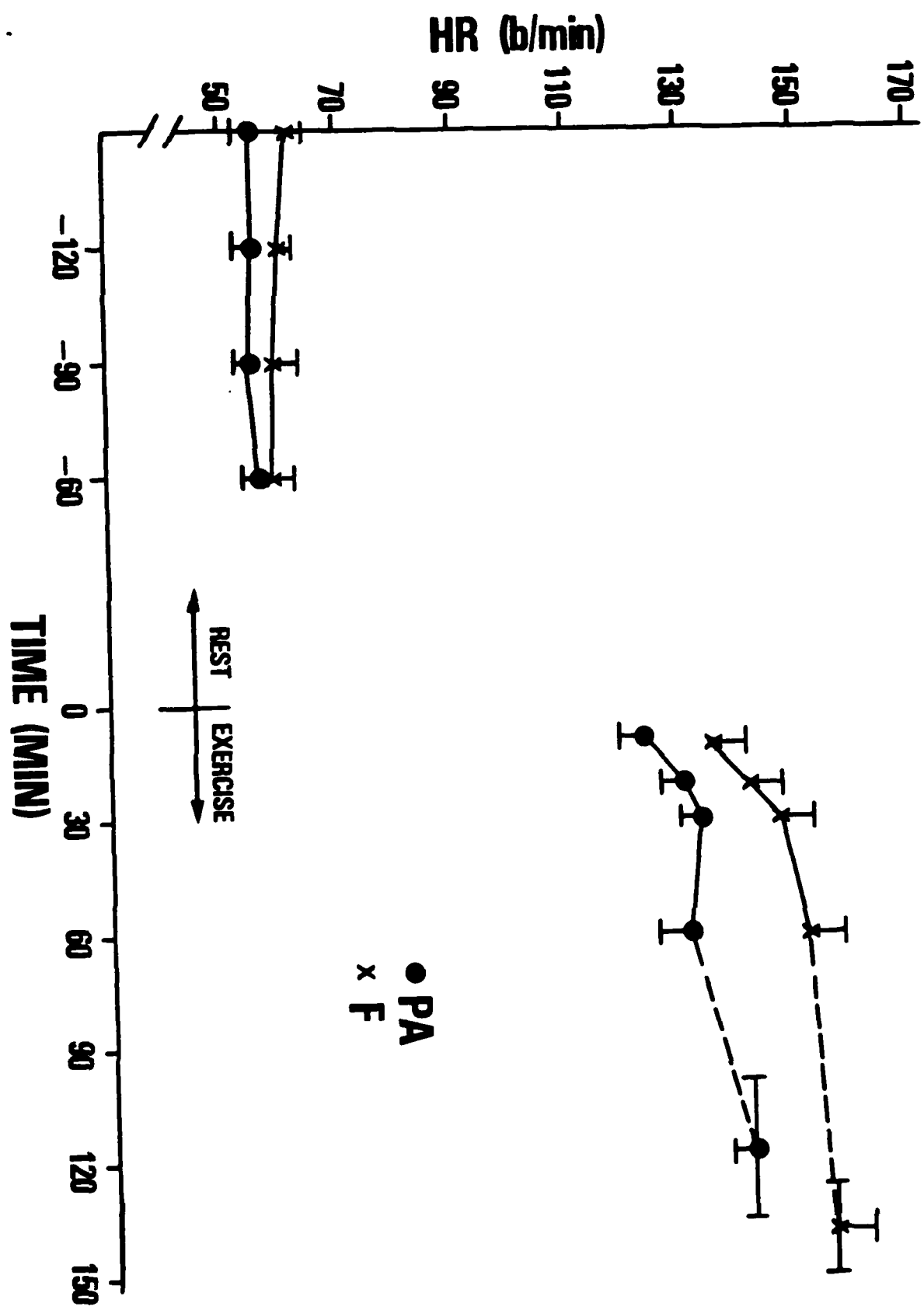
FIGURE 2B. EXPIRED GAS VOLUME

FIGURE 2C. HEART RATE











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